Macroeconomic Dynamics, **1**, 1997, 770–779. Printed in the United States of America.

NOTE

COORDINATION, CREDIT, AND AN ELASTIC CURRENCY

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The market economy is modeled as a decentralized joint production system. Markets in such an economy require the use of money or credit instruments to facilitate exchange. As a result, market economies are at risk for monetary instability induced by real-side production coordination failure. In particular, economies decentralized via centralized wholesaling markets are subject to precipitous collapses. The most stable monetary system is trade in specie. However, there very likely is a scarcity of specie, which generates inefficiency and discourages production. There is, then, a need for an elastic currency. Bank-issued bills of exchange are a perfectly elastic medium and eliminate the scarcity of specie and its attendant inefficiency, but are a less stable monetary system than is trade in specie. In the trade-off between elasticity and stability, fiduciary currency (or fiduciary deposits) lies between specie and bank-issued bills of exchange.

Keywords: Coordination Failure, Credit, Elastic Currency

1. INTRODUCTION

There is a surge in interest in coordination-failure models, spurred by the perception that there are insufficient external shocks, and inadequate propagation, in standard real business-cycle models [see, e.g., Christiano and Harrison (1996), Cooper (1997)]. At the same time, there is the natural perception that coordination-failure models treat purely real-side phenomena [see, e.g., Romer (1996)]. This note argues, in contrast, that coordination failure and monetary institutions are intimately intertwined. In particular, monetary instability reflects real-side coordination failure. At the same time, monetary institutions attenuate these coordination problems. With the increasing pace of financial deregulation, and the long history of monetary instability [see, e.g., Braudel (1979) and Del Mar (1903)], the link between coordination failure and monetary institutions is of ever more pressing interest.

The economy modeled in this note includes intermediate-goods producers, wholesalers, and final-product fabricators. This market structure immediately requires the use of money or credit instruments and is subject to precipitous collapses.

The author wishes to thank Herbert Simon and Richard Young for discussions of Simon's conjecture, and William Dewald, Thomas Saving, and seminar participants at the Federal Reserve Banks of Atlanta and St. Louis, and the NBER Summer Institute 1996 for valuable comments. Errors and oversights are the author's responsibility alone.
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 1365-1005/97 $9.00 + .10

2. JOINT PRODUCTION

An important source of coordination failure is joint production. Indeed, Evans et al. (1996, p. 30) identify this technological complementarity as the only plausible mechanism for generating macroeconomic coordination failure in actual economies. Consider the standard simple example of joint production that appears in Van Huyck et al. (1990), Crawford (1991, 1995), Anderson et al. (1996), Arifovic (1996), and Romer (1996, p. 298). A number of identical individuals work together as a team to produce an output, which then is divided equally. This equal division is consistent with standard models of bargaining. The total amount of output produced is determined by the least effort expended by any member of the team, which creates a bottleneck. Effort is unpleasant, but, if all individuals work equally, the additional output more than compensates for the additional effort. Consequently, all individuals are best off if all exert the maximum effort possible, but if any individual exerts less than the maximum, it is best for all other individuals to match that reduced effort level, so as not to waste any effort. Consequently, all effort levels that are equal across individuals are equilibria. Effort levels below the maximum effort possible are coordination failures, because these equilibria are Pareto ranked.

This paper exploits elaborations of this standard simple example of joint production. First, the input game is introduced, to allow for decentralized joint production. This decentralization generates a role for wholesaling in moving intermediate goods to final-product fabricators. It is demonstrated that centralized wholesaling markets are subject to precipitous collapses induced by real-side production coordination failure. Finally, currency and banking are explicitly introduced into the model. Specie is in limited supply, but is the most stable monetary system; bank-issued bills of exchange are perfectly elastic, but least stable; and fiduciary currency is intermediate in elasticity and stability.

3. INPUT GAME

The input game, which appears, for example, in Bryant (1983), Cooper and John (1988), and Milgrom and Roberts (1992), is a straightforward modification of the simple example of joint production. The identical individuals are endowed with leisure, and like consuming, just two goods—leisure and a single commodity. The commodity is made in a two-stage production process. In the first stage, the individuals work to produce intermediate goods. In the second stage, intermediate goods are combined effortlessly to make the commodity. Examples of intermediate goods include component parts, specialized machinery, and specialized labor services.

The production process involves a bottleneck. There is an equal number of individuals and intermediate goods, N. Each intermediate good is made by one preassigned individual. An hour of work produces a unit of intermediate good. In the second stage of production, the intermediate goods are combined to produce

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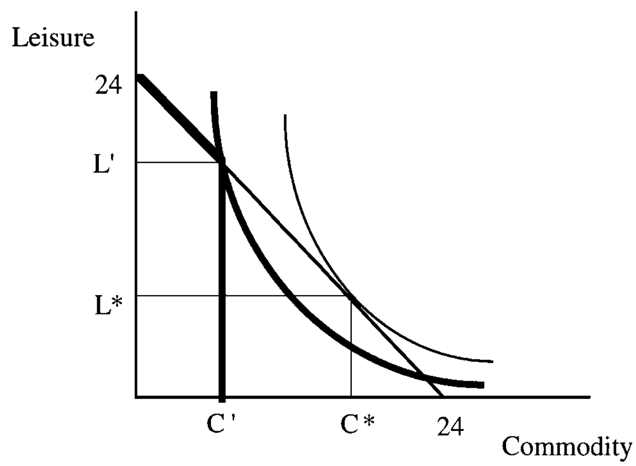

FIGURE 1. Coordination failure.

$N[\min(I_1, \ldots, I_N)]$ units of the commodity, where I_i are the units of the intermediate goods, $i = 1, \ldots, N$. The intermediate goods are nondurable, and a surplus of any of them is costlessly discarded as waste. Under usual assumptions on tastes, there is a unique optimal amount of work, and production of the commodity, in which equal amounts of the intermediate goods are produced. All amounts of work that are equal across individuals at or below the optimal amount are equilibria.

Figure 1 illustrates the input game. The budget line, running from 24 on the Leisure axis to 24 on the Commodity axis, is the combination of leisure and commodity available, assuming that equal amounts of intermediate goods are produced. The trade-off between leisure and commodity—1—is the real wage and the commodity price of intermediate good. The kinked bold budget set running from 24 on the Leisure axis to C' on the Commodity axis represents an equilibrium coordination failure, an underemployment equilibrium. It assumes that the minimum hours worked by another individual is $24 - L'$. The kinked bold budget set represents the real wage, or commodity price, of intermediate goods, subject to a quantity constraint. That is, in an equilibrium coordination failure, an underemployment equilibrium, the real wage, and the commodity price of intermediate goods are at their "competitive" market clearing levels—1. It is the self-validating perception of quantity constraints that is the problem, not prices.

The input game treats perfectly complementary inputs. Herbert Simon (1977, pp. 25–27) conjectures that such technological complementarities are a basic source of technological advance. Simon observes that technologically advanced production typically involves two basic steps: refining amorphous raw materials into uniform inputs and then recombining the inputs into complex products. First, you simplify, then you recomplicate. With greater technological advance, processes tend to become less adaptable, requiring greater uniformity of inputs, and inducing complementarity. Greater uniformity of inputs also allows the use of technologies with less ability to alter inputs to fit together. This improves efficiency, while the reduced ability to alter inputs to fit together implies greater complementarity between inputs. Simon's two basic steps of advanced production—refining and combining—can be separated, which introduces a role for wholesaling in moving refined intermediate goods to final-product fabricators. Moreover, joint production thereby extends to the market.

4. WHOLESALING AND THE INPUT GAME

A simple modification of the input game introduces wholesaling. Assume that there are many dispersed producers of each intermediate good, an equal number of producers of each. In addition to intermediate-goods producers, there are wholesalers and final-product fabricators. There is one wholesaler for each intermediate-goods producer. The final-product fabricators use the above bottleneck production technology. Moreover, wholesalers and final-product fabricators operate costlessly and are competitive. Consequently, wholesalers and final-product fabricators end up with none of the commodity, which all goes to the intermediate-goods producers. Indeed, the final-product fabricators pay the wholesalers a commodity price of 1 for intermediate goods, who then turn the entire proceeds of their sales over to the intermediate-goods producers.

It is first assumed that wholesalers take goods from intermediate-goods producers on consignment. Proceeds from sales are returned to the intermediate-goods producers, along with any unsold stock. This simplifies the strategic structure of the model, because the wholesalers do not themselves behave strategically. The consequences of any failure to sell the intermediate goods fall upon the intermediate-goods producers, not upon the wholesalers. In particular, the wholesalers are not working on a cash-and-carry basis, which would have them assume coordination risk. Thus, this assumption of consignment sales also serves to separate the properties of the wholesaling markets from the effects of the monetary system, which are treated later.

The wholesalers sell in centralized markets. Centralized wholesaling markets are modeled as specialized intermediate-goods terminals. The specialized wholesalers deliver their supply to their respective terminals, and then the final-product fabricators buy their inputs from the different specialized terminals. The wholesale terminals then turn the entire proceeds of the sales over to the wholesalers *in proportion* to their supply of intermediate goods. Any unsold stock also is returned proportionately. As a result, the costs of any unsold stock are shared by the intermediate-goods producers matched to the same terminal. Through these centralized markets, there is no matching of intermediate-goods producers individually to final-product fabricators. This alters the structure of the real-side coordination game. It also heightens the need for a monetary system.

Assume that intermediate-goods producers are numerous and small relative to the market. In particular, intermediate-goods producers ignore their own (negligible) effect upon their terminal's rate of payout. Then, with centralized wholesaling markets, there are only two equilibria, rather than a continuum.

PROPOSITION I. *With centralized wholesaling markets, the only positive output equilibrium is the optimal output equilibrium.*

Proof. Suppose a single intermediate good is scarce in an equilibrium. Then, the producers of that scarce good receive a price of 1 on their product, and would receive that same price of 1 on an incremental increase in their output as well. This follows because wholesale terminals charge final-product fabricators a price of 1, operate competitively and costlessly, and the wholesale terminal in question sells its entire stock, and could sell yet more. Hence, the intermediate-good producers in question must be producing the optimal amount (see Figure 1). (Because no intermediate-good producer would produce more than the optimal amount, we have a contradiction.) Suppose more than one intermediate good is scarce in equilibrium. The producers of these intermediate goods still receive a price of 1 on their product, and, because they are small, expect to receive that same price of 1 on an increase in their output as well. Hence, the intermediate-good producers must be producing the optimal amount, as claimed. ■

With centralized wholesaling markets, there is also the zero-output equilibrium. The general anticipation of zero output of intermediate goods is self-fulfilling. Given zero total output of any particular intermediate good, there is no use for the complementary intermediate goods, no production of these goods, and, with this anticipated, no production of the intermediate good in question, just as anticipated.

This result, that there are only two equilibria with centralized wholesaling markets—the optimal-output equilibrium and the zero-output equilibrium—may be of practical significance. Centralized wholesaling markets typically may be at their optimal level of production but be subject to occasional precipitous collapses. A sudden wave of pessimism is self-validating. Such occasional historical collapses of wholesaling markets are reported by, for example, Braudel (1979).

5. MONEY AND CREDIT

Wholesaling markets immediately require the use of money or credit instruments. Wholesalers need to pay intermediate-goods producers, final-product fabricators need to pay wholesalers, and intermediate-goods producers, as consumers, need to pay final-product fabricators. Interestingly, the work of Braudel (1979) suggests, indeed, that, historically, monetary innovation is linked to the increasing complexity of advancing commercial and industrial economies, and, in particular, to the extension of wholesale trade.

In the above wholesaling model, wholesalers take goods on consignment from intermediate-goods producers. Abandoning this assumption produces further insight into the behavior of the monetary system, and monetary instability. Monetary instability reflects real-side coordination problems while monetary institutions attenuate those coordination problems. Specifically, wholesalers, working on a cash-and-carry basis, free intermediate-goods producers from coordination risk, at least in so far as the monetary system is stable. However, it is the coordination risk itself that can render the monetary system unstable.

5.1. Model of Money

To study the monetary system, it is helpful to complicate the wholesaling model slightly. In addition to intermediate-goods producers, wholesalers, and final-product fabricators, there are banks. Like wholesalers and final-product fabricators, banks are assumed to have no endowments, to operate at zero cost, and to be competitive and consume no goods. All consumption is still by intermediate-goods producers. Specie is modeled as gold. In addition to leisure and the commodity, there is also gold. Intermediate-goods producers are endowed with leisure, each having an endowment of E_h hours of leisure, and with gold, each having an endowment of E_g units of gold. The banks can be thought of as goldsmiths. The banks have the unique ability to costlessly smith gold into a single gold consumption good. That is, all gold consumption good is the same. One unit of gold yields one unit of gold consumption good, and in this same 1-to-1 proportion for any scale of goldsmithing. The crucial feature of this goldsmithing technology is that it requires only gold. Intermediate-goods producers consume unsacrificed leisure, gold consumption good, and the commodity. The intermediate-goods producers all have the same utility function $U(C_h, C_g, C_n)$, where C_h is consumption of leisure, C_g is consumption of gold consumption good, and C_n is consumption of commodity. Intermediate-goods producers deposit their gold in banks. Wholesalers and final-product fabricators borrow gold from banks. Intermediate-goods producers produce, and their product is bought by wholesalers with gold. Wholesalers take the intermediate goods to their respective terminals, where final-product fabricators buy them with gold. Final-product fabricators fabricate the commodity, and it is bought by intermediate-goods producers with gold. Wholesalers and final-product fabricators return the gold to the banks. Finally, banks smith the gold into the gold consumption good, and it is withdrawn and consumed by the depositors—intermediate-goods producers.

The individual intermediate-goods producer's problem now can be described. Let W be the wage, or the price of intermediate good (which are the same by construction) in gold. Let P be the price of commodity, in gold. The price of gold consumption good in gold is 1 by construction. The intermediate-goods producer's problem is

$$\max_{H, C_g, C_n} U(E_h - H, C_g, C_n)$$
$$\text{s.t. } E_g + WH \geq C_g + PC_n.$$

The solution to this problem is that $W = U_1/U_2$ and $P = U_3/U_2$. Equilibrium conditions are that $C_g = E_g$ and that $C_n = H$. With the constraint holding with

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equality, $W = P$. These imply that

$$\frac{U_1(E_h - H, E_g, H)}{U_3(E_h - H, E_g, H)} = \frac{W}{P} = 1.$$

It further is necessary that there exist enough gold to support the trade, that is, as both wholesalers and final-product fabricators borrow from the banks, $E_g \geq 2PC_n = 2WH$.

The "moneyness" of gold is that the gold consumption good is made only with gold; it does not require multiple inputs. The gold consumption good itself is not subject to coordination problems. There can be a scarcity of such coordination-failure-free gold money, implying the need for an elastic currency. This observation is of historical importance; the need for an elastic currency has been expressed throughout monetary history, and the Federal Reserve System was set up expressly to provide an elastic currency. The possible consequences of a scarcity of gold are easily illustrated. The above solution requires $E_g \geq 2PC_n$. If the endowment of gold is less than this, it is an equilibrium for banks to pay depositors—intermediate-goods producers—interest on their deposits of gold. Then, when the banks lend gold to the wholesalers and final-product fabricators, they charge this same rate of interest, r. To pay back the loans, wholesalers must charge final-product fabricators $1 + r$ times the price they pay intermediate-goods producers, W. Similarly, the price that final-product fabricators charge, P, must be $1 + r$ times the wholesale price. The intermediate-goods producer's budget constraint changes. Now, that constraint is $(1+r)E_g + WH \geq C_g + PC_n$. Intermediate-goods producers withdraw some gold (the interest, in equilibrium) from deposits, after it is returned by wholesalers, to buy commodity. The requirement that gold support trade now is $E_g = WH + (1+r)WH = (2+r)WH$. It follows that $(1+r)^2 W = P$, and

$$\frac{U_1(E_h - H, E_g, H)}{U_3(E_h - H, E_g, H)} = \frac{W}{P} = \frac{1}{(1+r)^2}.$$

Hours worked, and production, are below their optimal levels. The return on production is reduced because of the necessity of covering the interest charges to wholesalers and to final-product fabricators. The rate of exchange between hours worked and commodity is reduced from the technological rate of exchange, 1.

The scarce gold equilibrium is an interpretation of the phrase "gold has value in trade in excess of its value in use." This interest rate does *not* reflect the rate-of-time preference. All consumption occurs at the same time in the model, expressly to highlight this effect of scarce gold. Hours worked, and production, are unambiguously below their optimal levels because this is a compensated (in income) reduction in the rate of exchange between hours worked and commodity. The interest payments go to the gold depositors—the intermediate-goods producers. If, counter to the above assumption, some intermediate-goods producers are endowed with gold and some are not, this involves an inefficient transfer of commodity to those endowed with gold. Such a transfer is consistent with historical complaints that New York banks artificially created a shortage of currency in order to enrich those holding gold.

The scarcity of gold raises the question of whether there is a solution to this scarcity. Indeed, bankers' acceptances, or bank-issued bills of exchange in gold (without gold backing) eliminate the scarcity of gold. The backing of the bank-issued bills of exchange in gold is loans to wholesalers and to final-product fabricators. Simply imagine that all agents accept bank-issued bills of exchange in gold, at par, in trade, and that all trade is carried on in bank-issued bills of exchange in gold. Furthermore, banks lend out whatever quantities of bank-issued bills of exchange in gold are demanded by wholesalers and final-product fabricators, at a zero rate of interest (the model has no rate-of-time preference). Then, optimality obtains. The scarce gold equilibrium encourages the use of bank-issued bills of exchange in gold as an alternative to trade in gold. Bank-issued bills of exchange in gold are the perfectly elastic currency.

A third, intermediate, monetary instrument is possible: fiduciary currency. Fiduciary (fractionally gold-backed) currency, or fiduciary deposits, reduce, or possibly eliminate, the scarcity of gold. For example, suppose that a fraction, δ, of fiduciary currency is backed by gold, but that the gold deposits of the intermediate-goods producers are not backed. The remainder of the backing of the fiduciary currency is loans to wholesalers and to final-product fabricators. Suppose $E_g \geq \delta 2WH$, all agents accept fiduciary currency (at par) in trade, all trade is carried on in fiduciary currency, and banks lend out whatever quantities of fiduciary currency are demanded by wholesalers and final-product fabricators, at a zero rate of interest. Then, optimality obtains. If, on the other hand, the above reserve requirement is binding, then there is a scarce gold equilibrium once again. Fiduciary currency is an imperfectly elastic currency.

5.2. Monetary Instability

Now, consider the possibility that, if wholesalers work on a cash-and-carry basis, this frees intermediate-goods producers from coordination risk. In particular, assume that wholesalers attempt to purchase the optimal amount of goods, as required by the positive output equilibrium of centralized wholesaling markets. The question is whether intermediate-goods producers might unexpectedly refuse to produce, because of a self-fulfilling fear that intermediate-goods producers do not produce. Do they ever refuse gold, because there remains an intermediate-goods-producer coordination problem, despite wholesalers working on a cash-and-carry basis?

The basic reason why gold might free intermediate-goods producers from coordination risk is very simple. Intermediate-goods producers, already paid in gold, do not have to worry about whether complementary intermediate goods have been produced. There is an obvious limitation on this ability of gold to free intermediate-goods producers from coordination risk, however. If no producers of complementary intermediate goods accept the gold in payment, they produce no intermediate goods, and there can be no production of commodity. The intermediate-goods producer accepting payment in gold is, then, only able to trade the gold for gold consumption good, not for the produced commodity. Depending upon the utility function, this might not be enough of a return to warrant the sacrifice of leisure. Specifically, the return is not enough if

$$W < \frac{U_1(E_h, E_g, 0)}{U_2(E_h, E_g, 0)}.$$

In this circumstance production collapses if economic agents stop producing, because they fear that others will stop producing. The inducement of being paid in gold cannot overcome this fear if the value of gold to the agent depends, to a strong enough degree, upon the ability to trade the gold for produced commodity. Perhaps "gold," besides being coordination-failure-free itself, is a good that has sufficient intrinsic value to keep this from happening.

Unlike gold, bank-issued bills of exchange in gold never free intermediate-goods producers from coordination risk. There always is a coordination problem in the acceptance of bank-issued bills of exchange in gold (without gold backing). An intermediate-goods producer who thinks that banks' bills of exchange in gold are worthless does not accept them in payment, and produces nothing. If all intermediate-goods producers think this way, then there is no production of commodity, and all banks' bills of exchange in gold are, indeed, worthless. Bank-issued bills of exchange in gold solve the scarcity of currency, but they do not free intermediate-goods producers from coordination risk. Perhaps this result explains, then, the occasional historical collapses in bills of exchange used in wholesale trade, reported by Braudel (1979). These panics typically were terminated by the arrival of large shipments of gold.

Use of fiduciary (fractionally gold-backed) currency, or fiduciary deposits, involves some risk of coordination problems for intermediate-goods producers, and therefore of monetary instability. In the trade-off between currency elasticity and monetary stability, fiduciary instruments lie between gold and bank-issued bills of exchange in gold. Suppose that, in the panic scenario, the holder of fiduciary currency expects to receive exactly the promised fractional gold backing, the fraction being δ. This might not be enough of a return to warrant the sacrifice of leisure. Specifically, the return is not enough if

$$W < \frac{1}{\delta}\frac{U_1(E_h, E_g, 0)}{U_2(E_h, E_g, 0)}.$$

Because $\delta < 1$, it is more likely that fiduciary currency does not free intermediate-goods producers from coordination risk than that gold does not do so. Perhaps this result explains the occasional historical banking panics reported, for example, by Del Mar (1903). However, with fiduciary currency, such a panic is not always a possibility, as it is with bank-issued bills of exchange (without gold backing).

Note that, if intermediate-goods producers are freed of coordination risk, wholesalers assume that risk. "Cash on the barrel head" shifts the risk; it does not eliminate it. Paying in gold does not solve a between-wholesalers coordination problem. The specialized wholesaler has to worry about whether wholesalers of complementary intermediate goods actually purchase those goods, because of the self-fulfilling fear that wholesalers do not purchase. In the first instance, in a

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wholesaling economy, a stable monetary system merely shifts the burden of coordination failure. However, the wholesalers' coordination problem, in practice, may be easier than the intermediate-goods producers' coordination problem. It is easier for wholesalers to meet and, in practice, they are fewer. Hence, stable monetary institutions may attenuate coordination problems. In theory, fully diversified wholesalers, paying in gold, do solve the coordination problem. However, fully diversified wholesalers are not practical.

The above analysis isolates an aspect of dynamics in that output decisions are made before returns are realized, production is multistaged, and purchasing is sequential. However, collapse is treated as multiple Nash equilibria, formally a static concept. It would be interesting to consider elaborations of the model involving repetitions of the game, and thereby capture the process of monetary collapse. Such analysis would be greatly aided by a better understanding of the dynamics implicit in Nash equilibrium. One might speculate that market and monetary structures influence dynamics in ways not captured by a simple listing of Nash equilibria, as suggested by the repeated experiments of Van Huyck et al. (1990).

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